Appendix A
Boiler Data

The raw data from several boiler logbooks (water chemistry logbook from January 2000 to May 2001,[1] stoker's logbook[2] from July 1997 through May 2003, four printouts from pressure recorders for boiler Nos. 22 and 23) were examined and converted to tables and graphs for ease of analysis. The following describes the findings.

Water Chemistry. The water chemistry logbook included daily readings on parameters such as phosphate, hydrazine, conductivity, chloride, pH, and alkalinity levels. The logbook also contained the amounts of GC,[3] adjunct-B,[4] Amerzine (hydrazine),[5] and SLLC-A[6] that were added to adjust the water chemistry.

Only the levels of hydrazine were tabulated for this report. Table 1 shows the levels of hydrazine in all boilers for a randomly selected year (January through December 2000). The green cells at the top of the table show where no data were available from January 1 to 26, 2000. No data were also available for several individual days (March 13, May 13, July 17, and November 29) and for 6 consecutive days in December (December 13 to 18). The blank areas in days where data were collected show where water chemistry readings were not taken because specific boilers were idle or under repair. The required level of hydrazine was between 0.03 and 0.1 parts per million (ppm).[7] Table 1 shows hydrazine levels within the specification limits in black, those above the limit in blue, and those below the limit in red. The far right column shows the monthly readings of water chemistry[8] taken by Drew Marine personnel during their on-site examination at the ship. The green cells in the monthly data again indicate months for which no records were found. Reviewing the data, the following was noted:

- Almost every time a boiler came out of an idle period (lay-up), the hydrazine level was zero or near zero for one or more days. After reaching the specified

[1] Norwegian Cruise Line (NCL) logbook containing water tests from January 2000 through May 2001.

[2] A record book containing information about when boilers are started, shut down, cleaned, skimmed, or blown-down and the fuel nozzles cleaned. Entries are made at each watch.

[3] GC is a concentrated alkaline liquid that neutralizes acid and controls corrosion.

[4] Adjunct B is a phosphate boiler water treatment chemical that works in conjunction with GC to control scale formation due to hardness.

[5] Amerzine (hydrazine) is a liquid catalyzed oxygen scavenger used to minimize oxygen corrosion in boiler steam and condensate systems. Amerzine also promotes the formation of protective iron and copper oxide films.

[6] SLLC-A is a condensate corrosion inhibitor made from a volatile liquid organic amine designed to minimize corrosion in steam and condensate systems by providing a pH environment, which neutralizes the effects of carbon dioxide.

[7] Drew Marine Control and Dosing chart, BW-CS-4 (May 2003).

[8] Drew monthly water chemistry service reports.

range, the levels typically stabilized and then were generally maintained within operational limits.

- In some cases, continued low levels of hydrazine were observed during operation. For example, in boiler No. 24 from July 27 to September 28, 2000, hydrazine levels were almost always below the specified minimum, at approximately 0.01 ppm.

- No records were found to show that hydrazine levels were built up before idle periods (for idle conditions, 150-200 ppm hydrazine was recommended).

- It appeared that boiler water chemistry readings were not taken on idle boilers in the wet condition[9] to assess the levels of hydrazine.[10]

According to interviews and documents,[11] typically two boilers were operated on a routine basis, with the third boiler operated during peak demand. The fourth boiler was typically idle for maintenance. Examination of the data in table 1 (yellow areas) confirmed that two boilers were operated on a routine basis, with a third coming on line as needed.

Cycles. The number of boiler cycles in a given period was quantified by collecting data from the stoker's logbook for several periods: one was chosen randomly and was from July 10, 1997, to July 15, 1998 (1 year), and the other was from January 2002 to the failure date of May 25, 2003 (17 months). One boiler cycle was defined as going from zero load to a full load of 60-62 bar and back to zero. Tables 2 and 3 summarize the data for these two periods, showing the number of boiler cycles and the amount of time the boilers were on and off. Tables 4A through 4C, which show raw data from the stoker's logbook in visual form, contain the following cycle data:

- All boilers from July 1997 to July 1998 (table 4A).

- Boiler No. 23 from April 2001 to December 2001 (table 4B).

- All boilers from January 2002 to May 2003 (table 4C).

Table 2 shows that, for a 1-year period from 1997 to 1998, the boilers accumulated between 11 and 29 cycles, with the average being 23 cycles that year or approximately one cycle every 2 weeks. Table 3 shows that from the beginning of 2002 through May 2003, the boilers accumulated between 18 and 26 cycles, with an average of 21.5 in about 17 months, or 15.2 per year. Pressure charts and interviews with personnel indicated that when the boilers were shut down, they were typically brought to zero pressure. Therefore, the boiler pressure cycles were from zero pressure to the operating

[9] The wet condition was when the boiler was shut down but still sealed and full of water.

[10] Based on when water chemistry readings were taken in the logbook and interviews.

[11] NCL interoffice memo, March 16, 1998.

pressure of 62 bar (900 psi) and back to zero. It should be noted that the boilers were often started and shut down within 1.5 days or less, frequently in less than 0.5 day.

Idle Periods. Tables 2 and 3 also show the amount of time the boilers were on and off. The red data indicate periods when the boilers were shut down for 20 or more days, and the blue data indicate periods when the boilers were shut down for 10 to 20 days. Table 2 (1997-1998) shows that the boilers were shut down for 10 or more days between two and seven times each in this period. Boiler No. 21 was not shut down for 20 or more days, boiler No. 22 had one instance where it was off for more than 20 days, boiler No. 23 had two instances, and boiler No. 24 had six instances. Table 3 (2002-2003) shows that in 17 months, the boilers were shut down between three and seven times each for 10 days or more. Boiler No. 23 had one instance where it was shut down for more than 20 days, boiler No. 21 had two instances, and boiler No. 24 had three instances.

Startup and Cooldown. Four printouts from the boiler pressure recorders were examined to determine the rate of pressure buildup and dropoff. Table 5 summarizes the data. The question marks signify interrupted recordings, meaning that a full reading could not be obtained: either the recorders stopped before dropping to zero pressure or the boilers started back up in the middle of the cycle.

The data indicate that the boilers went from zero pressure to a full pressure of 60-62 bar in 1.5 to 5.5 hours. The average ramp-up rate was 3.4 hours. According to the charts, the boilers were fired at 10-minute intervals and shut down for 10 minutes until the boilers reached pressure. That practice is consistent with the boiler startup procedure in the original operating manual.[12]

The rate of pressure drop from full pressure to zero ranged between 45 minutes (0.75 hours) and 4 hours, with an average of 2.8 hours. No expected pressure cooldown time was found in the original operating manual or other records.

[12] *Liner France, Propulsion Machinery, Operation and Maintenance Guide*, vol. 3, "Boilers," p. 26.

2000																															MONTHLY
January	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	22
21																											0	0	0	0.01	0.05	
22																											0.05	0.05	0.07	0.07	0.07	
23																											0.05	0.05				0.05
24																																0
February	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28				19
21	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.1	0.1	0.07	0.07	0.1	0.1	0.07	0.07	0.1	0.1	0.07														
22	0.07	0.07	0.07	0.07						0.07	0.07													0.07	0.05	0.1	0.1	0.07				
23			0														0	0.03	0.07	0.07	0.07	0.07	0.1	0.07	0.05	0.1	0.07	0.07				0.06
24				0	0.01	0	0.03	0.01	0.01	0.01	0.03	0.07	0.07	0.07	0.07	0.1	0.1	0.05	0.07	0.07	0.07	0.07	0.07	0.07	0.03							0.07
March	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	25
21		0.01	0.01													0.01	0.01					0	0.03							0		
22	0.3	0.07	0.07	0.07	0.07	0.07	0.1	0.1	0.07																					0.03		
23	0.2	0.07	0.07	0.1	0.07	0.07	0.1	0.1	0.05	0.3	0.2	0.05	?	0.2	0.05	0.03	0.05	0.1	0.05	0.05	0.2	0.03	0.03	0.1	0.1	0.07	0.07	0.1	0.2	0.03	0.1	0.1
24									0	0.03	0.05	0.03	?	0.1	0.07	0.05	0.05	0.1	0.05	0.05		0.03	0.03	0.07	0.1	0.07	0.07	0.1	0.1	0.03	0.1	0.1
April	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30		22
21																			0	0	0.03	0.03	0.05	0.05	0.07	0.1	0.05	0.05	0.03	0.03		0.03
22						0.01				0.01			0.03													0.01	0.03	0.05	0.03	0.05		
23	0.1	0.1	0.1	0.3	0.2	0.05	0.07	0.3	0.03	0.03	0.1	0.1	0.03	0.1	0.2	0.07	0.07	0.1	0.07	0.07									0	0.01		
24	0.1	0.1	0.1	0.2	0.2	0.05	0.07	0.2	0.03	0.03	0.1	0.1	0.03	0.1	0.1	0.07	0.07	0.07	0.05	0.02	0.1	0.07	0.07	0.1	0.07	0.1	0.07					0.07
May	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	
21	0.03	0.07	0.07	0.07	0.1	0.07	0.05	0.05	0.1	0.05	0.03	0.03	?					0.01	0.03	0.07	0.05	0.03	0.07	0.07	0.05	0.03	0.07	0.07	0.07	0.07	0.05	
22	0.05	0.1	0.07	0.05	0.07	0.07	0.07	0.05	0.1	0.07	0.05	0.05	?	0.07	0.07	0.07															0.05	
23	0.01			0.01				0			0.01	0.03	?	0.07	0.07	0.07	0.07	0.05	0.05			0.01			0.03	0.03					
24																	0.01	0.01	0.01	0.01	0.03	0.03	0.01	0.05	0.05	0.03	0.03	0.07	0.07	0.07	0.07	
June	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30		
21	0.05	0.05				0.01		0.03	0.05	0.07	0.07	0.05	0.05	0.05	0.03	0.03	0.03	0.05	0.05	0.07	0.05	0.05	0.05	0.07	0.05	0.05	0.07	0.05	0.05	0.07		
22	0.05	0.05	0.07	0.05	0.05	0.05	0.03	0.05	0.05	0.07	0.07	0.05	0.05	0.05	0.03	0.03	0.03	0.05	0.05	0.07	0.05	0.05	0.05	0.01	0.07	0.05	0.08	0.05	0.05	0.01		
23	0.01	0.08	0.07	0.05	0.05	0.03	0.07																									
24								0.01	0.03					0	0.01						0.03	0.03						0.03	0.03			
July	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	
21	0.07	0.07	0.07	0.07	0.07	0.03	0.07	0.07	0.07	0.07	0.07	0.1	0.05	0.1	0.2	0.05	?	0.05	0.07	0.03	0.05	0.1	0.05	0.07	0.07	0.07	0.05	0.03	0.07	0.05	0.05	
22	0.07	0.07	0.07	0.07	0.07	0.05	0.07	0.07	0.07	0.07	0.07	0.07	0.05	0.1	0.1	0.05	?	0.07	0.1	0.05	0.05	0.1	0.01	0.07	0.1	0.07	0.05	0.05				
23						0.01							0.02							0.01	0.03									0.01	0.03	
24																											0	0.01	0.01	0.02	0.01	
August	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	
21	0.05	0.1	0.05	0.03	0.1	0.05	0.05	0.1	0.05	0.03																				0	0.03	
22						0.03	0.05	0.1	0.05	0.03	0.03					0.01	0.01						0.05	0.07	0.05	0.1	0.05	0.07	0.07	0.1	0.05	
23			0.05	0.03					0.01	0.02	0.05	0.07	0.1	0.1	0.1	0.07	0.05	0.1	0.1	0.1	0.15	0.1	0.2	0.07	0.07	0.1	0.07	0.07	0.07	0.07	0.05	
24	0.01	0.01	0.01	0.01	0.01							0	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.03	0.02							
September	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30		
21			0.03	0.05	0.1	0.07	0.07																									
22	0.07	0.2	0.03	0.07	0.1	0.07	0.07	0.1	0.07	0.05	0.07		0.03	0.07	0.07	0.1	0.07	0.05	0.07	0.07	0.03						0.01	0.03	0.1			
23	0.07	0.15	0.05	0.03	0.1	0.07	0.07	0.1	0.07	0.05	0.07	0.1	0.03	0.07	0.07	0.1	0.05	0.05	0.07	0.07	0.03	0.07	0.07	0.07	0.05	0.07	0.07	0.03		0.05		
24										0	0.01	0.01	0.01	0				0.01			0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.03	0.03		
October	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	
21																																
22					0.01	0.03	0.07	0.07	0.07	0.07	0.07	0.03	0.05	0.07	0.05	0.05	0.05	0.05	0.05	0.03												
23	0.05	0.05	0.07	0.07	0.05	0.05	0.07	0.07	0.07	0.07	0.07	0.03	0.05	0.07	0.05	0.05	0.05	0.05	0.05	0.03	0.05	0.07	0.05	0.07	0.07	0.07	0.05	0.05	0.05	0.07	0.07	
24	0.03	0.03	0.05	0.07	0.03	0.03						0.01	0.03						0.01	0.01	0.01	0.05	0.05	0.07	0.07	0.05	0.05	0.05	0.05	0.05	0.05	
November	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30		18
21	0.01	0.01	0.01						0.01	0.01	0.01	0.03	0.03	0.05	0.05	0.05	0.07	0.07	0.05	0.03	0.03	0.03	0.03	0.05	0.05	0.05	0.05	0.05	?	0.03		0.07
22																						0.01	0.01	0.03	0.07	0.05	0.05	0.05	?	0.04		
23	0.05	0.05	0.05	0.05	0.05	0.05	0.1	0.07	0.05	0.07					0.01	0.03													?	0.01		
24	0.07	0.05	0.05	0.05	0.05	0.05	0.1	0.07	0.05	0.01	0.05	0.05	0.05	0.05	0.05	0.05	0.07	0.03	0.05	0.03	0.03	0.03	0.01	0.05								0.03
December	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	16
21	0.06	0.06	0.06	0.05	0.06	0.05	0.05	0.05	0.06	0.06	0.07	0.07	?	?	?	?	?	?			0	0.01		0.01	0.1			0.03	0.03	0.03	0.05	
22	0.07	0.06	0.05	0.05	0.07	0.06	0.06	0.06	0.06	0.06	0.07	0.07	?	?	?	?	?	?	0.05	0.05	0.03	0.05	0.07	0.05	0.05	0.07	0.1	0.05	0.05	0.05	0.05	0.1
23							0.04	0.04					?	?	?	?	?	?	0.03	0.05	0.03	0.05	0.07	0.05	0.05	0.07	0.07	0.05				0.05
24																																

Hydrazine Content
Limits 0.03-0.1 ppm

Table 1: 2000 Hydrazine Content

July 10, 1997 to July 15, 1998

	BOILER OPERATION TIME (DAYS)							
	BOILER 21		BOILER 22		BOILER 23		BOILER 24	
	ON	OFF	ON	OFF	ON	OFF	ON	OFF
cycle 1	0.5	2.5	1.5	12.5	>17	10.5		>37
2	0.5	9.5	16.5	8	21	8.5	8.5	41
3	1.5	1.5	33.5	0	2	3.5	20	4.5
4	12.5	5.5	8	9	8.5	5.5	44.5	26.5
5	1.5	4.5	0.5	1.5	1.5	1.5	15.5	12.5
6	1.5	6.5	1.5	5.5	12.5	6.5	8	7.5
7	16	5	6	22	0.5	11	6.5	27
8	2	0	1.5	1.5	6.5	1.5	39.5	8.5
9	9.5	1.5	2.5	1.5	0.5	7.5	0.5	4
10	0.5	7.5	1.5	2	22.5	12.5	1	23.5
11	19.5	0	2	14.5	8.5	3	3.5	31
12	0.5	1	23.5	13.5	0.5	1.5	>0.5	
13	1.5	1.5	14.5	6.5	12.5	1.5		
14	12.5	19.5	7.5	6	5.5	0.5		
15	15.5	5.5	27	5.5	2.5	3		
16	8.5	3	1	1	0.5	1.5		
17	1	5	1.5	5.5	1.5	10.5		
18	5	3.5	1.5	5.5	0.5	1.5		
19	0.5	1.5	2	3	1.5	2.5		
20	13.5	0	0.5	4.5	1.5	1.5		
21	23	5.5	2	5.5	1.5	5.5		
22	1.5	3.5	39	3	22.5	3.5		
23	0.5	1.5	9	0.5	0.5	20.5		
24	1.5	3.5	22	>0.5	28.5	3.5		
25	0.5	1.5			5.5	22.5		
26	58	5			12	11		
27	23	12.5			3	0		
28	11	3			4	>2		
29	0	4						

Summary Data

AVG DAYS ON	8	9	7	15
AVG DAYS OFF	4	6	6	19
Cycles	29	24	28	11

Table 2: 1997-1998 Boiler Cycling Summary

January 1, 2002 to May 25, 2003

		BOILER OPERATION TIME (DAYS)							
		BOILER 21		BOILER 22		BOILER 23		BOILER 24	
January 2002		ON	OFF	ON	OFF	ON	OFF	ON	OFF
	cycle 1	>12	4	>48	1	1.5	5.5		**>15**
	2	3.5	2	27.5	2.5	16	1.5	0	13
	3	7.5	1	46.5	**16.5**	12	3	0.5	**13.5**
	4	3.5	5.5	58.5	1	29	1	0	6.5
	5	43.5	3.5	33.5	0	46	**16.5**	0	**35.5**
	6	3.5	3.5	14.5	3.5	1.5	2	0	13.5
	7	3.5	**12.5**	12.5	**10**	5	2.5	35.5	0.5
	8	75	3.5	8.5	2.5	32.5	**16.5**	0.5	**44.5**
	9	1	2	18.5	9.5	18.5	5.5	16	4.5
	10	8	**16.5**	11.5	2.5	5.5	5	1.5	0.5
	11	6.5	5.5	4.5	2.5	30	2.5	0.5	0.5
	12	6.5	**15.5**	4.5	2.5	13.5	9.5	2.5	1.5
	13	8.5	4.5	4.5	2.5	1.5	1.5	2	0.5
	14	3	8	12	2	57.5	2	0.5	0.5
	15	19	9.5	33	2	5.5	1	2	1.5
	16	2	**42**			5	**17.5**	2.5	0.5
	17	35	1.5					19.5	0.5
	18							21	1.5
	19							11.5	8.5
	20							5.5	0.5
	21							13.5	4.5
	22							30.5	2.5
	23							8.5	**16.5**
January 2003	1	5.5	0.5	40.5	1.5	3.5	2.5	18.5	**19.5**
	2	12.5	2.5	13	2.5	1.5	1.5	1	5
	3	2.5	**29.5**	25	**12.5**	85.5	**26.5**	29	**23.5**
	4	50.5	0	>37		>9		>51	
	5	7	0						
	6	9.5	>8						
		Failure 5/25/2003							

Summary Data

AVG DAYS ON	14	24	19	11
AVG DAYS OFF	8	4	7	9
2002-2003 cycles	23	18	19	26

Table 3: 2002-2003 Boiler Cycling Summary

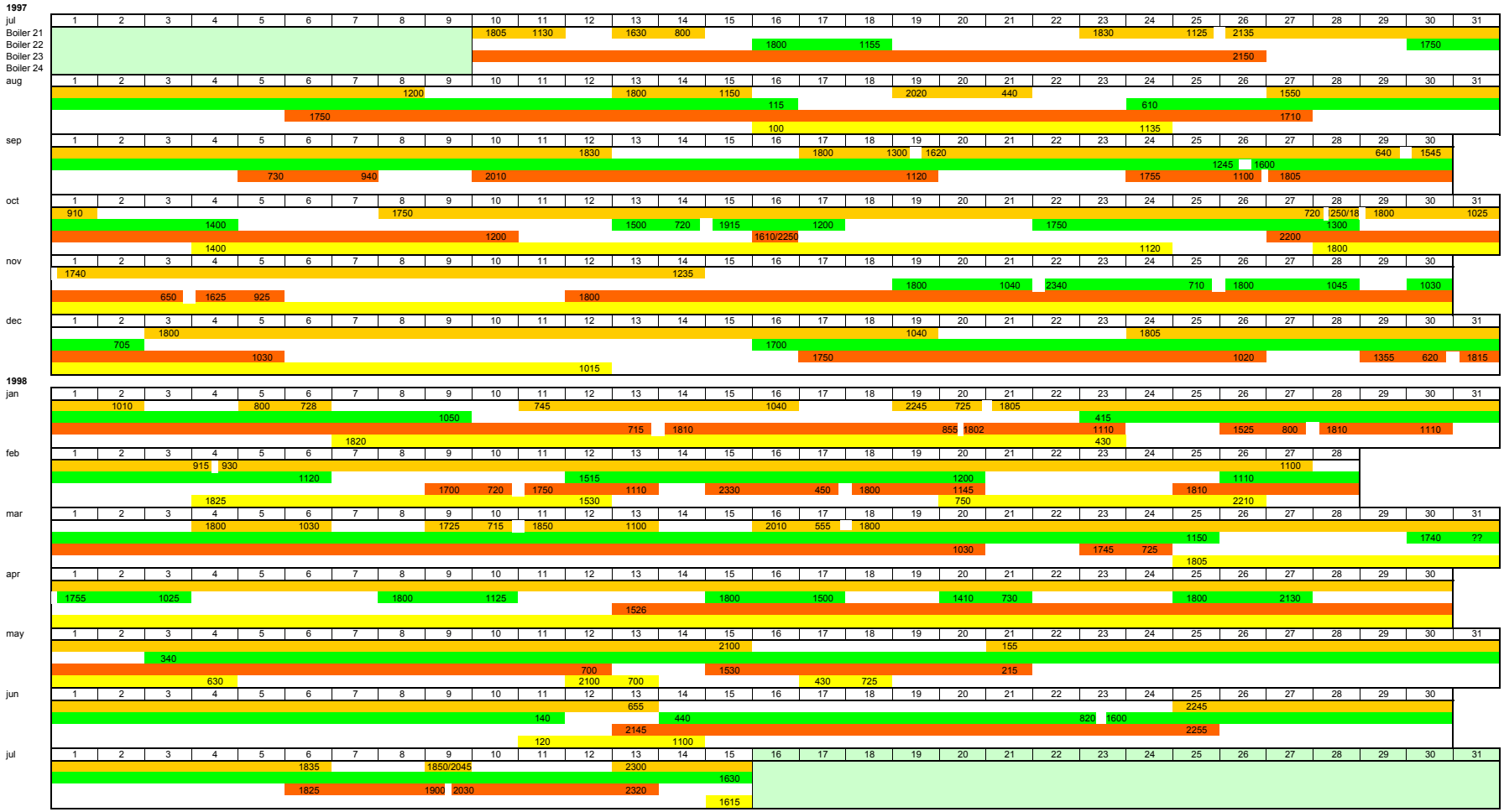

Table 4A: 1997-1998 Boiler Cycling Raw Data

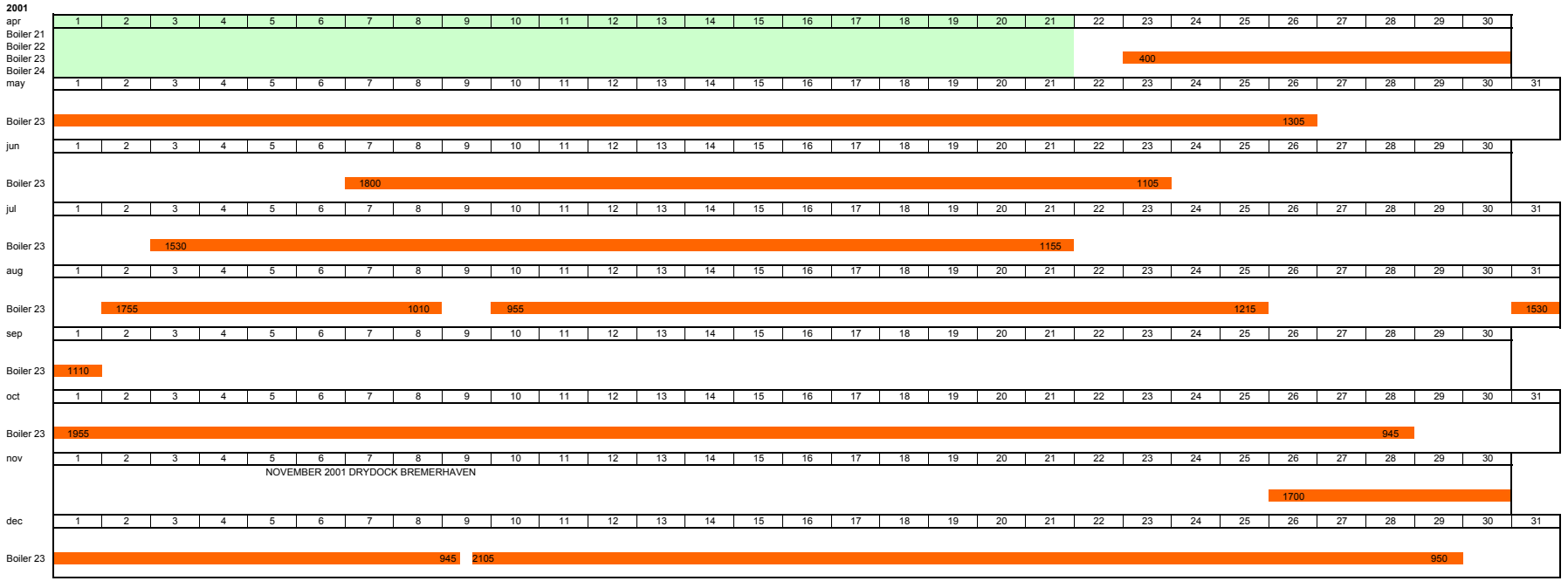

Table 4B: 2001 Boiler 23 Cycling Raw Data

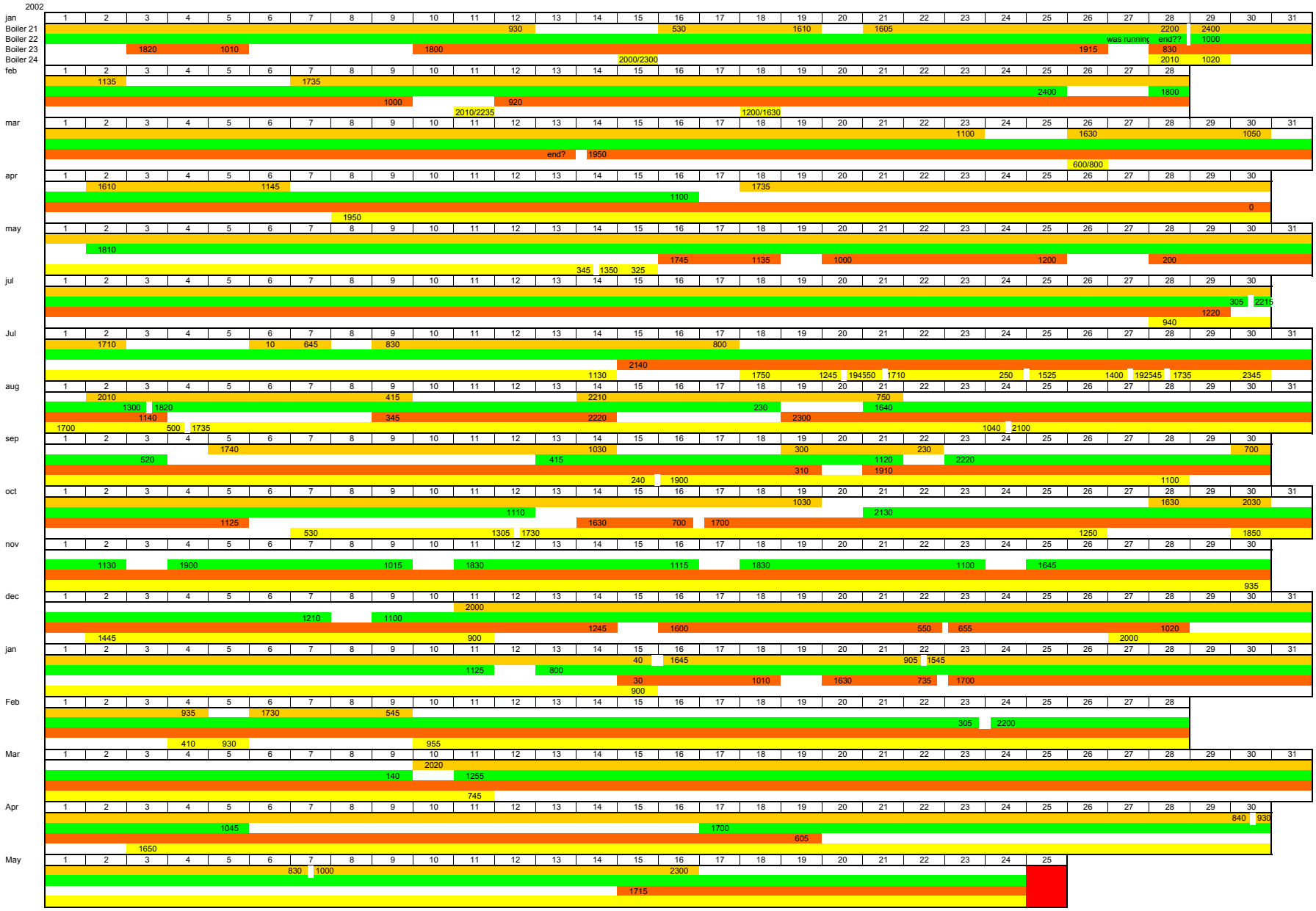

Table 4C: 2002-2003 Boiler Cycling Raw Data

Roll	Boiler	Ramp-Up Time (hrs)	Cool-Down Time (hrs)
NTSB D023	22		0.75
15-Dec-02		?	1
		?	?
		3	?
		3.5	2.5
		3	3
		2.75	?
		3	2.5
		3	
NTSB D024	23	4	?
19-Oct-02		?	2.75
		?	3
		3	?
		3.5	2.75
		?	?
		?	
NTSB D025	23		4
17-Mar-03		4	?
		?	?
		3.5	?
		3	?
		5.5	?
		?	
NTSB D026	22		?
31-Mar-02		?	2.5
		3	?
		1.5	2
		3.5	
	Average	3.4	2.8

Table 5: Boiler Transients